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Tropical Cyclone Ensemble Data Assimilation

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LONG-TERM GOALS

The ultimate goal of this project is to demonstrate that when tropical cyclones (TCs) are present in the atmosphere, a multi-scale approach for data asssimilation can significantly ehnance the analysis and forecast of the TC and the forecast of the effects of the TC on the larger scale atmospheric processes (e.g., through the extratropical transition (ET) of the TC into an extratropical cyclone). Our multiscale approach is based on coupling a lower resolution global data assimilation system and a higher resolution limited area data assimilation system for the region where TCs develop and evolve. The coupled approach has the potential to lead to a better utilization of the computer resources in atmospheric modeling.

OBJECTIVES

Ours is the first attempt to use an ensemble-based coupled global-limited-area data assimilation system to improve the analysis and forecast of TCs, and the forecast of the effects of the TCs on the larger scale atmospheric processes. In fact, to the best of our knowledge, we have been the only research group working on the development of a global data assimilation system that uses a higher resolution limited area component to enhance the analysis in a selected region . Our key scientific objectives are to find the optimal configuration of the coupled system and to explore its potentials and limitations. Our goal is to assess the skill of our coupled system by a reanalysis of observations from the TCS-08 field program. Our plan is to make this reanalysis available to the community working on the scientific analysis of the observations from TCS-08. We hope that our product will contribute not only to the development of improved forecasting capabilities, but also to an improved understanding of the physical processes associated with the genesis and evolution of tropical cyclones.

APPROACH

Our data assimilation system is based on the Local Ensemble Transform Kalman Filter (LETKF) algorithm (Ott et al. 2004; Hunt et al. 2007) and its specific implementation on the NCEP GFS model (Szunyogh et al. 2005 and 2008). The first effort led by the PI to build a coupled global-limited-area data assimilation system was described in Merkova et al. (2010). That paper compared the performance of four different coupling strategies: three strategies propagated information in one

Report Documentation Page

Form Approved
OMB No. 0704-0188

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1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
2010		**00-00-2010 to 00-00-2010**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Tropical Cyclone Ensemble Data Assimilation	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Texas A&M University,Department of Atmospheric Sciences,3150 TAMU,College Station,TX,77843-3150**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**5**	

direction, from the global to the limited area system, while the fourth strategy also propagated information in the other direction, from the limited area system to the global system. The system described in Merkova et al. (2010) was designed for an extended North-American region. Our plans for the current project called for starting the development of a system for the North-Pacific region based on the existing system for North-America. Since Merkova (2010) found that the performance of two of the four coupling strategies weas clearly superior to the others, we decided to implement only two strategies on the North-Pacific region. One of these strategies uses fully cycled versions of both the global and the limited area data assimilation systems. This configuration allows for an accurate representation of the effect of uncertainties in the lateral boundary conditions on the uncertainties in the initial conditions in the limited area domain. The second strategy is similar to the first one, except that information is also propagated from the regional to the global system.

Because we have had extensive experince with the global component of the data assimilation system for summer 2004, we decided to carry out the initial testing of the system for the North-Pacific using observations from the 2004 Typhoon season. This decision was also motivated by the extensive experience our collaborators from AER Inc. had with Quick-Scat data for the same period (e.g., Hoffman and Leidner 2010).

The development and testing of the coupled data assimilation system is carried out at Texas A&M University under the supervision of the PI. The key members of the Texas A&M group are Christina Holt, a graduate research assistant, whose full support for FY10 was provided by the current ONR grant, and Gyorgyi Gyarmati, an Assistant Research Scientist (whose full support for FY10 was provided by Texas A&M). The observation operators used in the assimilation of advanced satellite observation products, such as the Quick-Scat data, are developed by AER scientists Ross Hoffman and Mark Leidner.

WORK COMPLETED

We have completed implementing our system on the North-Pacific region. We have successfully completed a reanalysis of observations for a two-month perod of the 2004 Typhoon Season using the one-way coupled configuration. Results from this reanalysis are shown in the next section.

RESULTS

To illustrate the performance of the data assimilation system, we show analyses for two particular analysis times in Figure 1 and 2. Both figures show analyses for times when Typhoons Mindulle (10) and Tingting (11) were in an early phase of their development. These systems developed into typhoons two days apart (June 23 and 25) from the monsoon trough. Mindulle later developed into a category 4 typhoon and was responsible for 56 deaths and $833 million in damage, while Tingting developed into a category 1 typhoon. The two figures show the mean-sea-level pressure for both the global analysis (upper panel) and the limited area analysis (lower level). The global analysis has a spectral resolution of T62 (about 270 km at 15^0N), while the limited area analysis has a resolution of 48-km. The analyses were obtained by assimilating all observations which were operationally assimilated in real time by NCEP, except for the satellite radiance observations and the Quick-Scat data. (We also assimilated dropsonde observations from the DOTSTAR program, but such observations were not available for the times we show here.) To assess the quality of the analyses, we also show the best track position and intensity from the Joint Typoon Warning Center (JTWC).

Both the global and the limited area analysis systems perform well in locating the center of the cyclonic circulations. This is somewhat surprising in the case of the global analysis considering its low spatial resolution. We emphasize that we do not use "TC relocation", an approach employed even in the state-of-the-art data assimilation system used for the Climate Forecast System Reanalysis (CFSR, Saha 2010). An important positive result is that the limited area analysis can take advantage of its higher resolution to improve the analysis of the location of the TC.

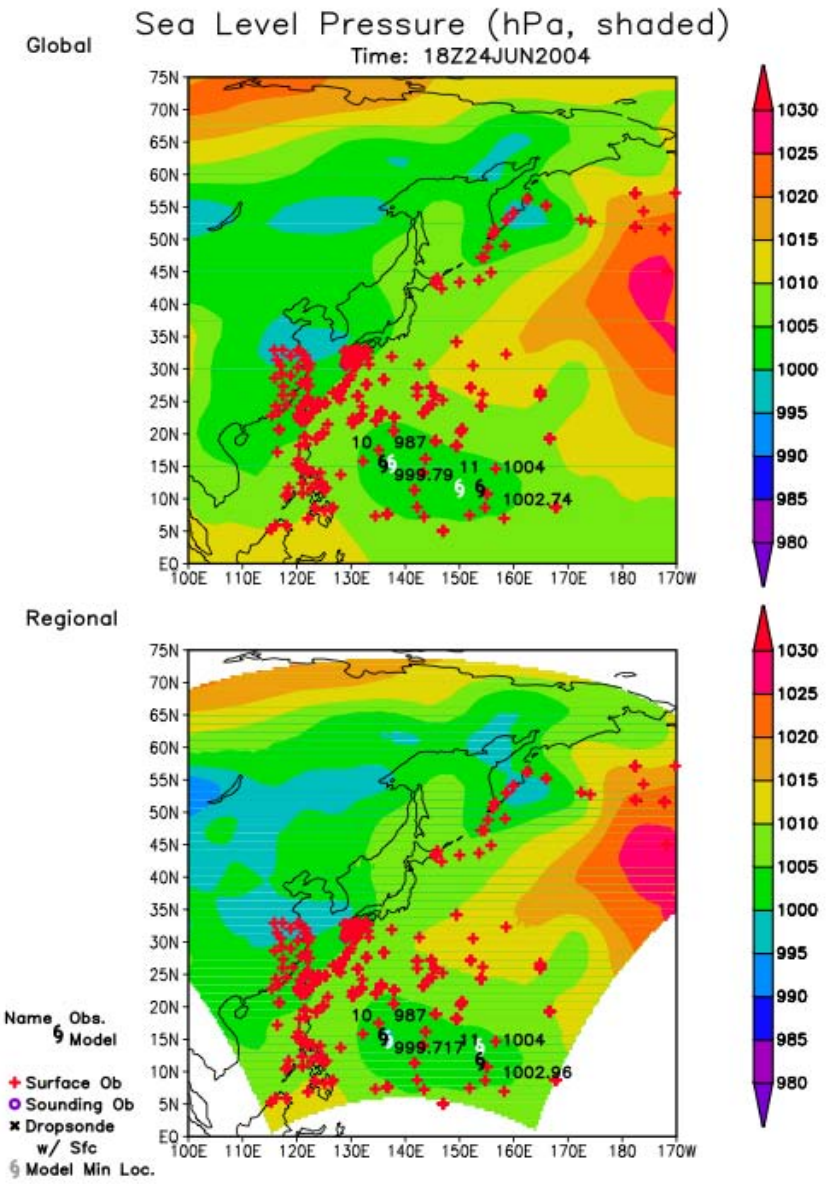

Figure 1 Analysis of the mean-sea-level pressure in the global (upper panel) and limited area component (lower panel) of the assimilation system. TC symbols show the analyzed (white) and best track estimate (black) of the TC location. The locations of observations of some selected types are also shown (see legend). On the right-hand-side of each TC symbol, the top value shows the best track estimate of the intensity, while the bottom value shows the analyzed intensity.

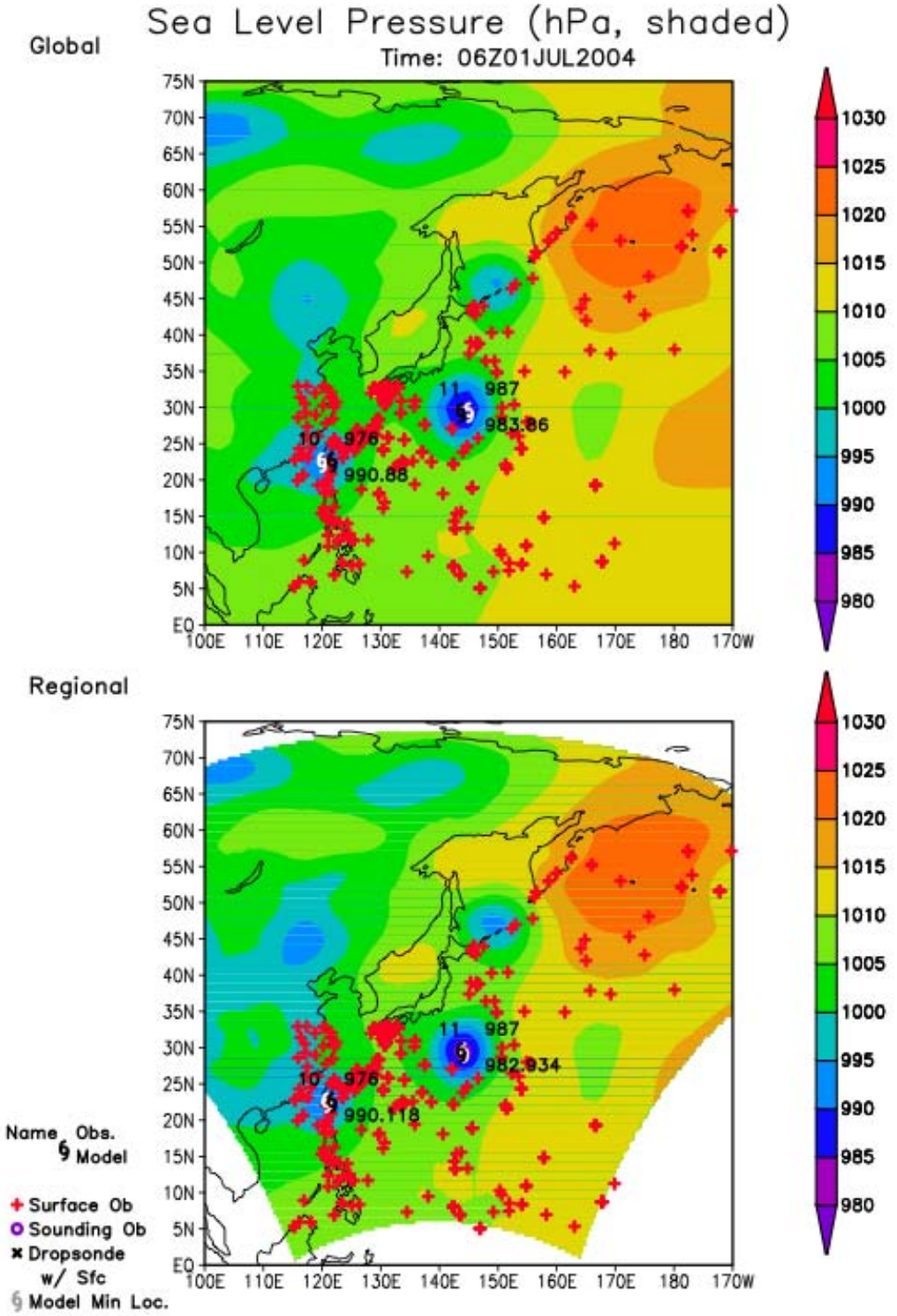

Figure 2 Same as Figure 1, except for a later analysis time.

IMPACT/APPLICATIONS

Our results add to the growing body of evidence that ensemble-based Kalman filters provide an efficient way of data assimilation in the presence of TCs. In particular, ensemble based Kalman filters do not require the use of "TC relocation", an approach used in some of the variational data assimilation systems to improve the analysis of the location of the TCs. Our results also indicate that a coupled global-limited-area data assimilation system can take advantage of the higher resolution in the region where TCs form and evolve. The next steps of our research will be as follows:

- Implement the observation operator developed by our AER collaborators for the Quick-Scat observations.
- Carry out a reanalysis for the same period of the 2004 Typhoon Season with the configuration of the data assimilation system that feeds back information from the limited area system to the global system.
- Carry out experiments at higher resolutions of the limited-area system.
- Start generating analyses with the TCS-08 observations.
- Start investigating the forecast impact of the coupled data assimilation approach. (So far we have investigated only the analysis effects.)

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